Near Field Intensity Trends of Main Laser Alignment Images

NIF shots from January 2009 through October 2012

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Abstract

The National Ignition Facility (NIF) utilizes 192 high-energy laser beams focused with enough power and precision on a hydrogen-filled spherical, **cryogenic target** for initiating a **fusion** reaction. NIF has been operational for four years and during that time, more than 1100 successful firings or shots have occurred.

Critical instrument measurements and camera images carefully recorded for each shot. The result is a massive and complex database or '**big data**' archive that can be used to understand the state of the laser system at any point in its history or to locate and **track trends** in the laser operation over time.

In one such study, the optical light throughput for each of the 192 beams was measured over a 3 year period in order to verify that any change in **transmission rate** of the optics performed within **design expectations**. Differences between **average intensity** from images recorded before the input sensor package (ISP) and after the output sensor package (OSP) in the NIF beamline were examined.

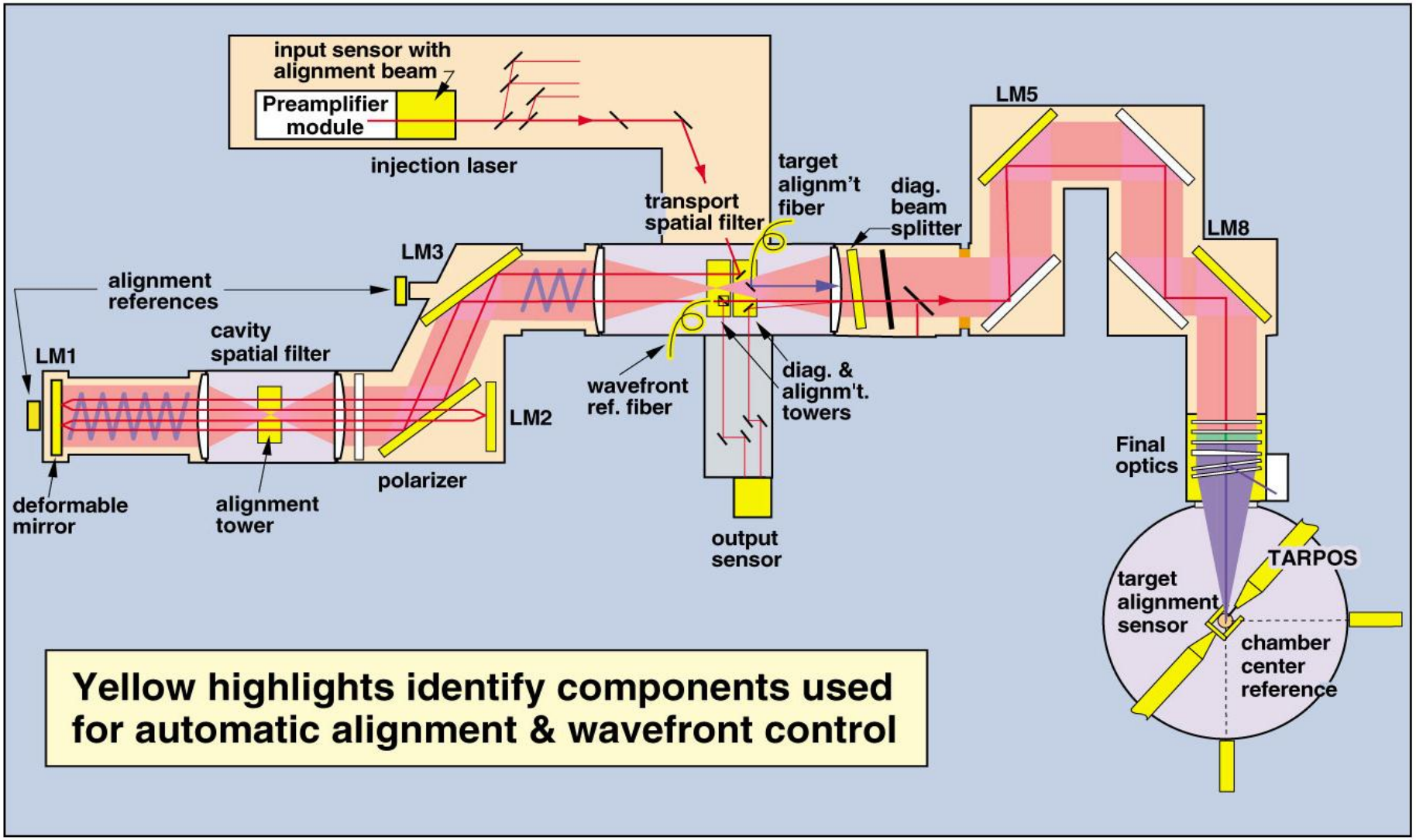
We discuss the metric for quantifying the change in **transmission rate** and the resulting trends. Results are presented that illustrate the change in **light transmission** through the lens over a 3 year timeframe.

Introduction

Optical throughput was evaluated from the Input Sensor Package (ISP) to the Output Sensor Package (OSP) through the NIF Main Laser amplifiers using archived alignment images and device settings

- **Data Set**
  - Over three years of system-shot alignment data from January 2009 through October 2012
  - Parameter variation for beam-line 111 (B111)
- **Method**
  - Definition of the Metric
  - Image processing
- **Results**
  - Composite “movie” of alignment images for Q11T
  - Trend plots for Q11T and Q16T
- **Conclusions & Future work**

NIF Beampath



Description of the NIF Beampath from the ISP to the OSP

- The alignment pilot beam is a 1053nm cw laser injected into the NIF beampath at the ISP after the pre-amplifier module
- The beam is split evenly four ways using a series of three, half-waveplates and three polarizers so that one ISP pilot beam services four, or a “Quad”, of Main Laser beams
- Each beam is injected into the Main Laser via the Transport Spatial Filter (TSF)
- The beam makes the first of two passes through the Power Amplifier before entering the Main Amplifier Cavity
- The beam traverses the Main Amplifier four times before being ejected;
  - A half-waveplate in pass 2 rotates the polarization of the beam so that it passes through the polarizer and remains trapped in the main amplifier
  - A half-waveplate in pass 3 rotates the polarization of the beam so that it is reflected by the polarizer out of the main amplifier
- The beam passes out of the main Amplifier and through the Power Amplifier a second time and is picked-off near the focus of the TSF and sent to the OSP where it is imaged with a CCD camera.

Data Set

Archived alignment parameters

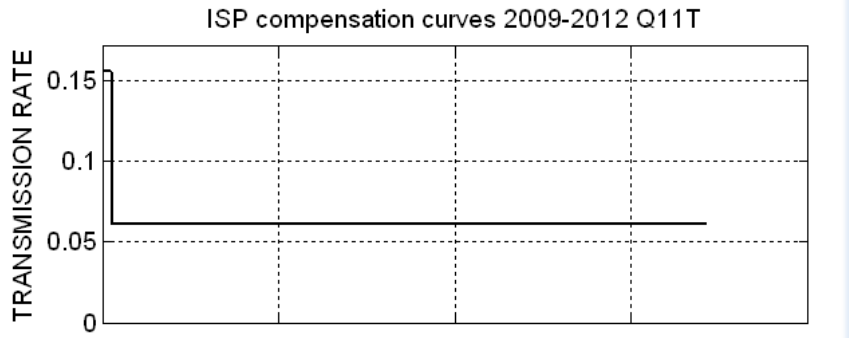
- **Over three years of system-shot alignment data from January 2009 through October 2012**
  - — Near Field alignment images (ISP & OSP)
  - — Transmission, Exposure, and Gain (TEG)
    - – Attenuator Transmission set-points (ISP & OSP)
    - – Camera Exposure set-points (ISP & OSP)
    - – Camera Gain set-points (ISP & OSP)
- **Excluded:**
  - — Alignments including fewer than four OSP beams in a quad
  - — Known off-normal images
- **Leveraged tools**
  - — Image downloader for large image set requests
  - — Database query tools

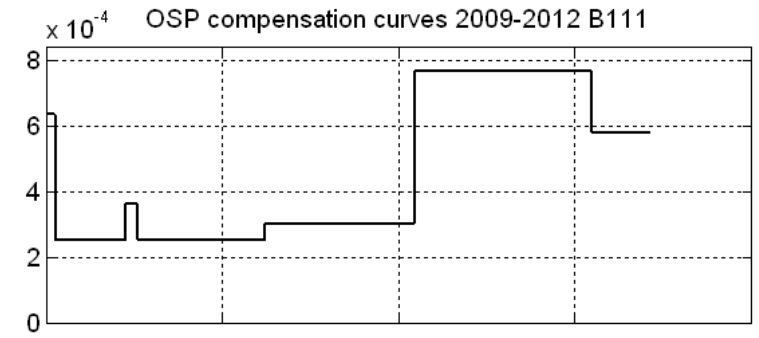
SHOT_ID	ISP_LOCATION	ISP_REQUEST_ID	ISP_GAIN	ISP_TRANSMISSION_RATE	ISP_EXPOSURE_TIME	ISP_LOOP_NAME
N090109-001-999	Q12B	123149199003600	1	0.052591	0.15	AA_ISP_CL_ALIGNMENT
N090109-001-999	Q12B	123149340077900	1	0.052591	0.15	AA_ISP_CL_ALIGNMENT
N090109-001-999	Q12B	123149398724400	1	0.052591	0.15	AA_ISP_CL_ALIGNMENT

SHOT_ID	OSP_LOCATION1	OSP_REQUEST_ID1	OSP_GAIN1	OSP_TRANSMISSION_RATE1	OSP_EXPOSURE_TIME1	OSP_LOOP_NAME1
N090109-001-999	B125	123149231888400	1	0.001292	0.1	aa_isp_lm3_tsf_p4
N090109-001-999	B125	123149231888400	1	0.001292	0.1	aa_isp_lm3_tsf_p4
N090109-001-999	B125	123149231888400	1	0.001292	0.1	aa_isp_lm3_tsf_p4

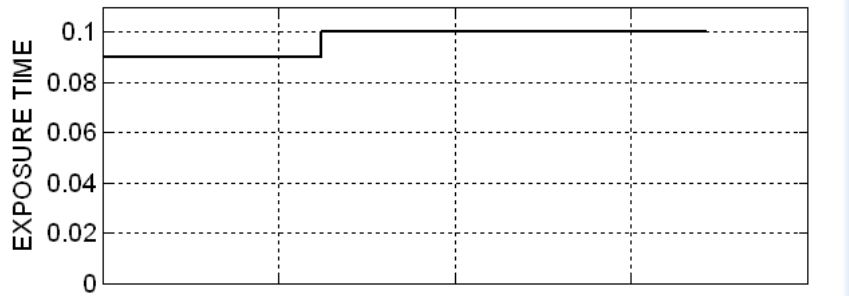
Data Set

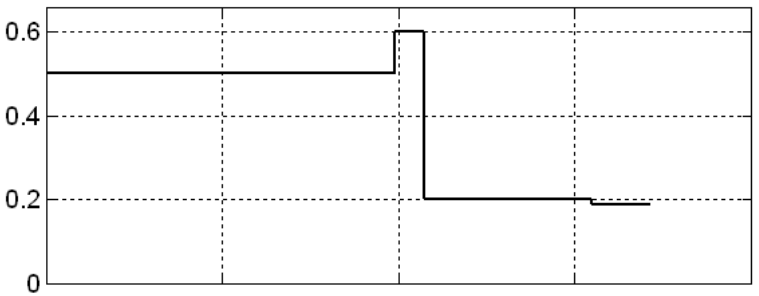
Q11T (B111) parameter variation

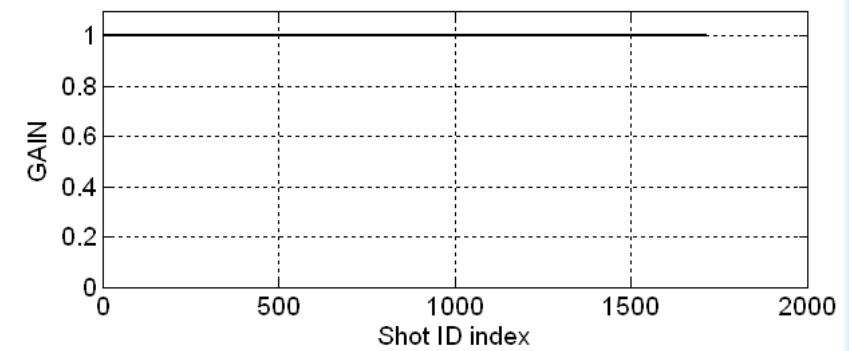


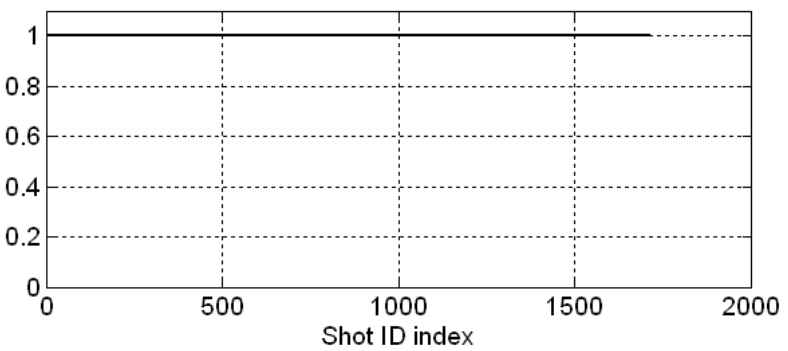


Changes in “TEG” parameters tend to pre-date laser replacements









ISP

OSP

Method

Definition of the Metric

Measured from archived image

$$N = \#\,pixels \qquad at\ 25\%\ beam\ footprint$$

$$I_\mu = \frac{1}{N}\sum_{i=1}^{N} x_i \qquad mean\ intensity$$

Read from shot archive data base

$$T = transmission\ rate$$

$$E = exposure\ time$$

$$G = gain$$

Compensated ISP Intensity (1 quad)

$$I_{ISP} = \frac{I_\mu}{TEG}$$

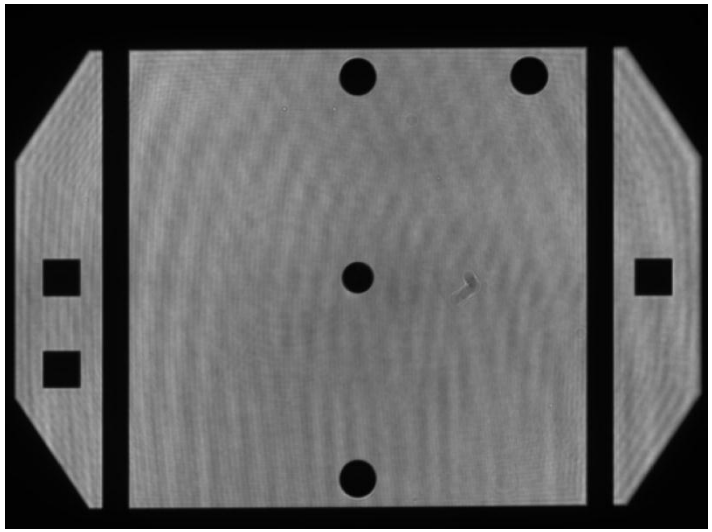
Compensated OSP Intensity (4 beams)

$$I_{OSP} = \frac{1}{4}\left(\frac{I_{\mu 1}}{T_1 E_1 G_1} + \frac{I_{\mu 2}}{T_2 E_2 G_2} + \frac{I_{\mu 3}}{T_3 E_3 G_3} + \frac{I_{\mu 4}}{T_4 E_4 G_4}\right)$$

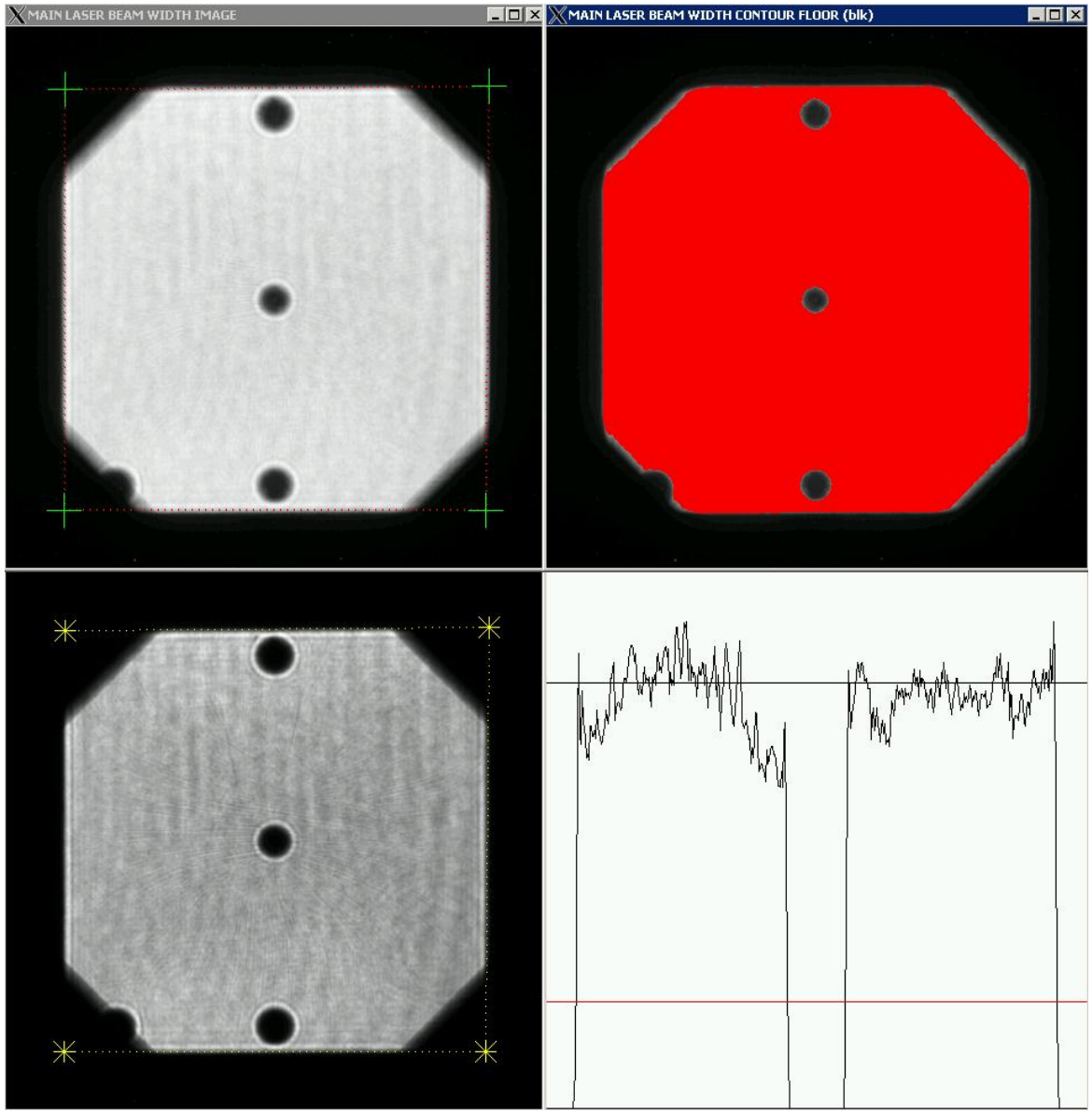
$$\boldsymbol{M = \frac{I_{OSP}}{I_{ISP}}}$$

Method

Image processing

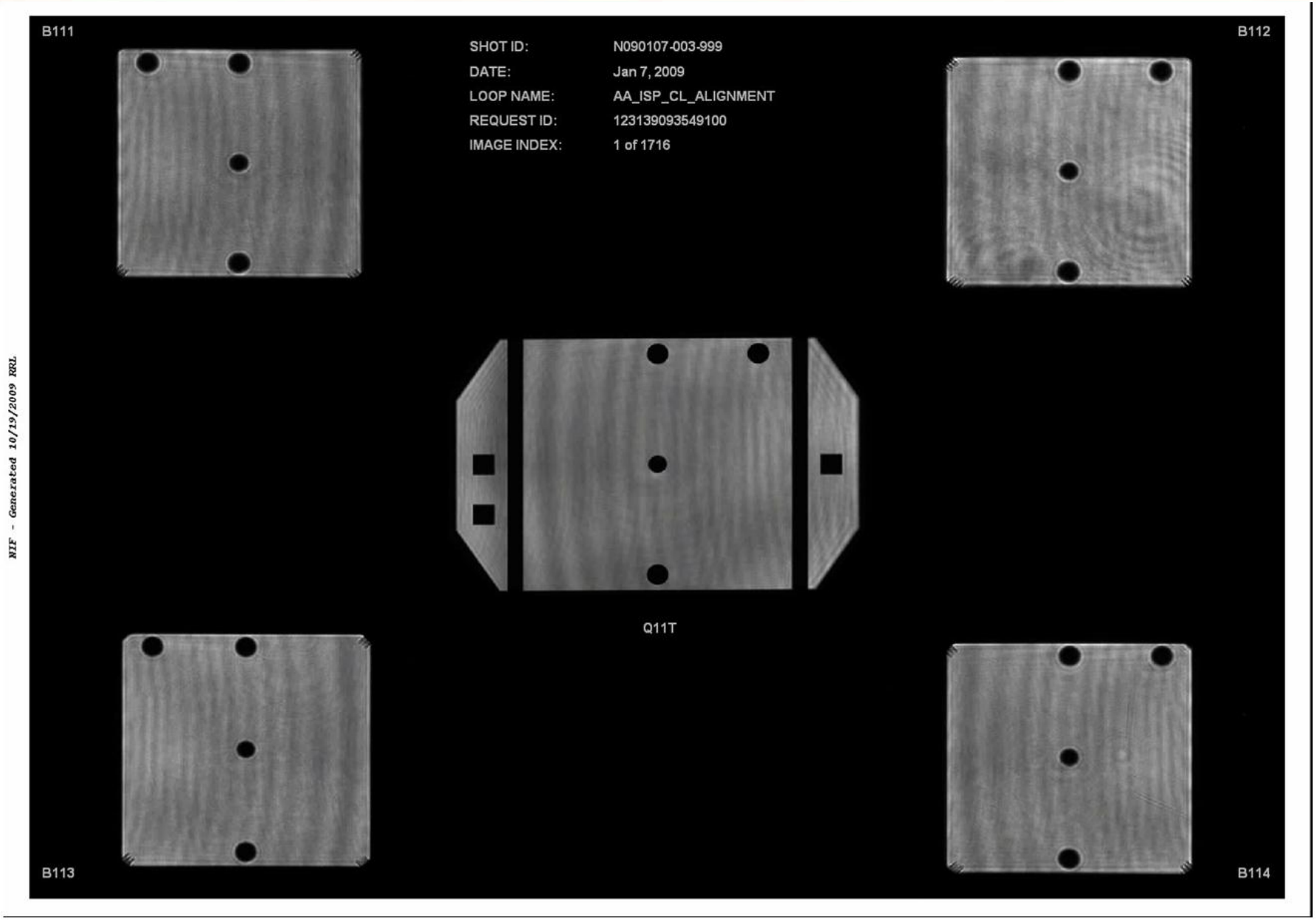


- Use beam-area code for consistent measurements
- Threshold the beam at 25% beam level
  - ISP wings excluded
  - Holes excluded
- Reported parameters
  - Integrated counts
  - # of pixels
  - Mean counts & Stdev
  - Min & Max
  - Saturation %
  - Beam corner coordinates



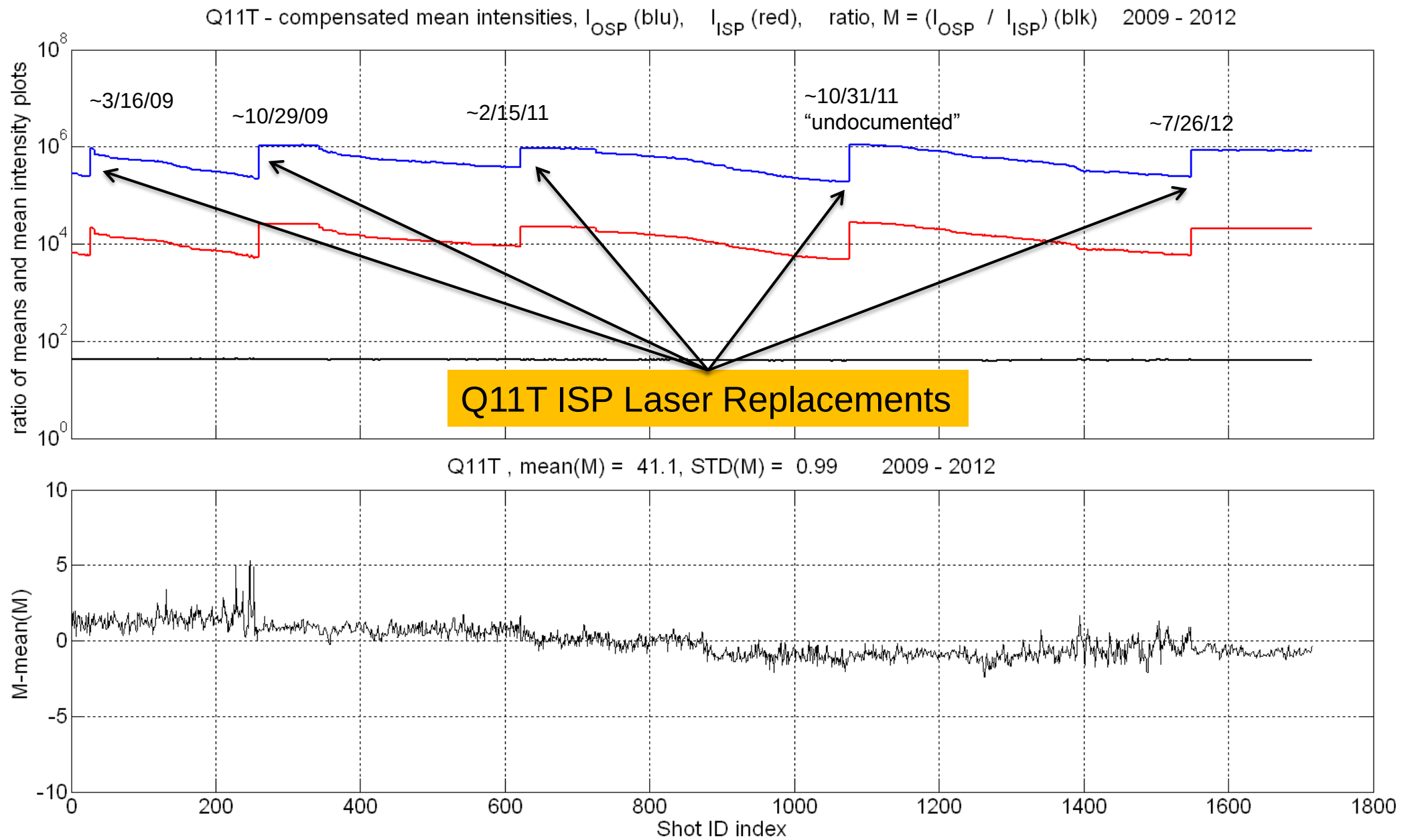
Results

Composite "movie" of alignment images for Q11T



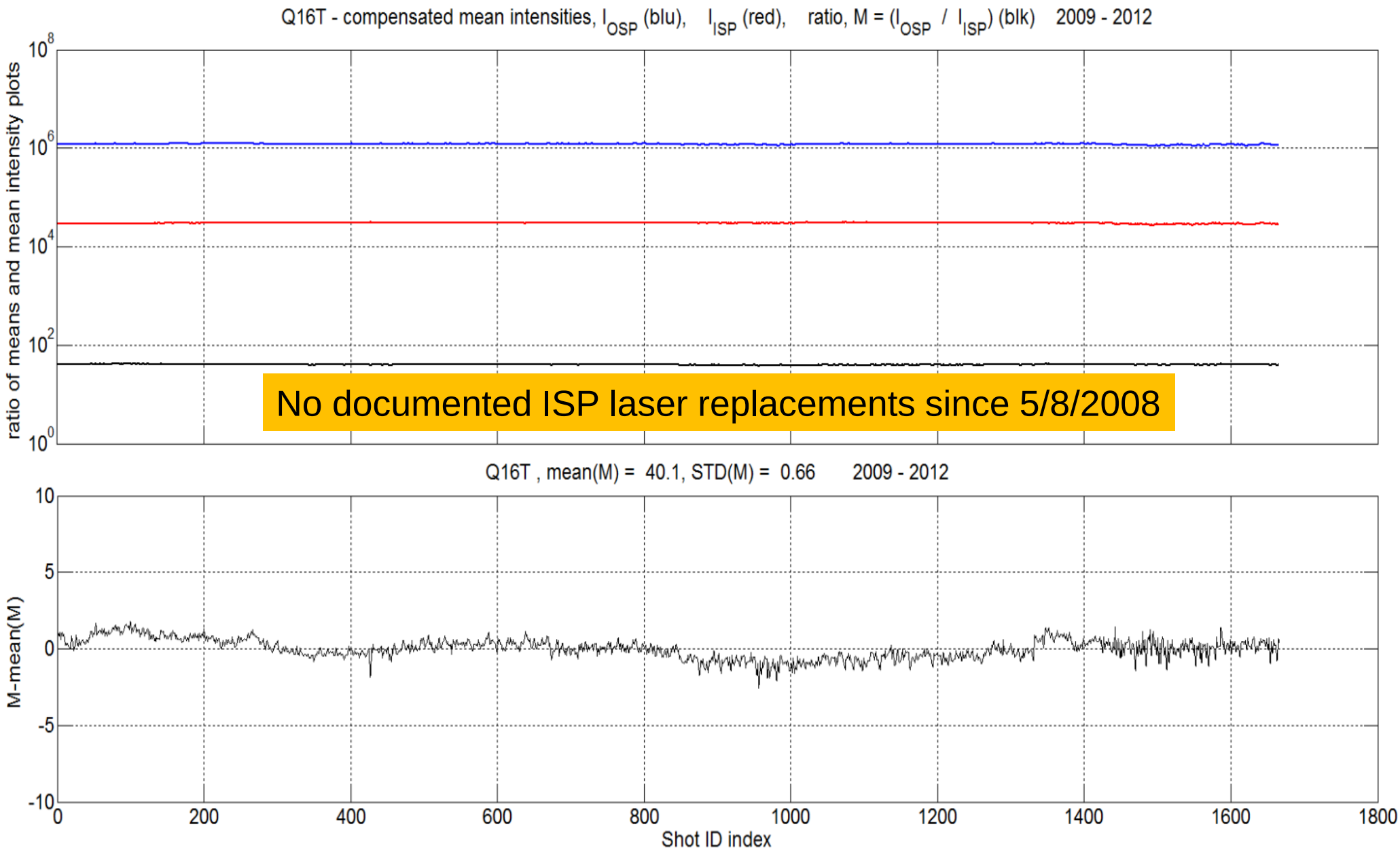
Results

Trend plot for Q11T; 2009 – 2012 (~1700 shots)



Results

Trend plot for Q16T; 2009 – 2012 (~1700 shots)



Conclusions & Future Work

- OSP/ISP integrated intensity ratio is a potential indicator of optical throughput from ISP to OSP
  - Signal shows very little change over three years (variance <2%)
  - Appears to be susceptible to laser replacements which may be a calibration issue with the attenuators
  - Data has not been reconciled with machine history of half-wave plate positions
  - Increased noise appears to correlate/pre-date laser replacements in Q11T
- Future work
  - reconcile measurements with machine history of half-wave plate positions
  - Plot trends for remaining quads
  - Deeper correlation between trend “features” and LRU transactions
  - Determine effects of CCD attenuator calibrations on the ratio


NIF